DOCUMENT RESUME

ED 254 438 SO 016 203

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TITLE Development of Data Analysis Units Designed to Enhance Reasoning and Knowledge Transfer in the College Level Economics Course.
PUB DATE Mar 84
NOTE 21p.; Paper presented at the Annual Meeting of the Southwestern Economics Association (Fort Worth, TX, March 24, 1984). Appendix B, the computer program, was not included in the document as received by ERIC. It is available from Robert F. Hodgin, Economics Department, University of Houston at Clear Lake City, Houston, TX 77058-1098.
PUB TYPE Reports - Descriptive (141) -- Speeches/Conference Papers (150)

EDRS PRICE MF01/PC01 Plus Postage.
DESCRIPTORS *Data Analysis; *Economics Education; Educational Objectives; Educational Research; Higher Education; *Instructional Improvement; *Models; Student Projects; *Teaching Methods

ABSTRACT

This paper presents the elementary mathematics behind the traditional cost-volume-profit model of the business firm in both deterministic and probabilistic forms. By a simulation process the structure could be modeled to derive a wide variety of data analysis sets for use in the classroom. The data sets can be used to aid students in applying concepts learned in the classroom. The results of four such data sets completed by students in a managerial economics course are summarized. Initial feedback indicates that students found the data sets useful. Although the examples are basic, the procedures are adaptable to complex problems. By assuming multivariate normal distributions, students can incorporate risk considerations and probability measures relating to different levels of profit into the analysis. The student can be introduced to progressively harder problems within a consistent framework. The problems used in this experiment are given in the appendix. (IS)

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DEVELOPMENT OF DATA ANALYSIS UNITS DESIGNED TO ENHANCE REASONING AND KNOWLEDGE TRANSFER IN THE COLLEGE LEVEL ECONOMICS COURSE

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SP 016 203

Paper presented at the Annual Meeting of the Southwestern Economics Association (Fort Worth, TX, March 24, 1984).

ACKNOWLEDGEMENTS

The authors wish to express their thanks to the Joint Council on Economic Education for its financial support of this project.

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DEVELOPMENT OF DATA ANALYSIS UNITS DESIGNED TO ENHANCE REASONING AND KNOWLEDGE TRANSFER IN THE COLLEGE LEVEL ECONOMICS COURSE

INTRODUCTION

This paper will present a theoretical basis for and a preliminary application of data analysis units designed for knowledge enhancement of economic concepts in the college course. The underlying learning assumption is that knowledge transfer can be enhanced by way of a technique. The unique feature of the approach is the versatility of the potential units which are to be deductively analyzed by the student. The testable hypothesis involves assessment of whether or not the students' transfer of conceptual knowledge is improved. However, at this early stage of development, emphasis will be placed upon the framework for the approach.

The design of the pedagogical economic model to generate the data analysis units incorporates the cost-volume-profit (CVP) approach for the traditional theory of the firm. The CVP approach serves well as a unifying construct for many analyses. Utilizing some elementary statistical concepts and various modifications of the assumptions for the model, data sets conforming to an array of contemporary industrial settings are possible. Elementary courses may utilize the data generating capability of the approach in a deterministic fashion for the certainty case in introductory theory while more advanced courses may utilize the stochastic capabilities for the uncertainty case. By working with the data sets, given specific questions, the student is potentially better able to integrate fundamental economic concepts into a general framework of knowledge.

The next section of the paper discusses the structure of the simulation process through a simple schematic. Section three introduces the theoretical analysis which follows from modifications and extensions of models in the literature. Section four explains the system for generating the data units and indicates the consistency of the procedure with the theoretical base. The fifth section shows the results of student efforts on an early data analysis problem set. The major thrusts of the work are reviewed in that final section.

THE APPROACH

The encyclopedic approach to teaching economics does little to instill the student with critical thinking skills. The instructor is saddled with the task of presenting an expanding body of knowledge to a less sophisticated student population. The student, all too often, leaves the course with little knowledge that will be transferred to situations meaningful to him. The outcome of the approach at hand, if successful, would be to elevate a vague intuitive feeling on the student's part to a level of formal analysis for each concept so addressed.

The generation of the data sets is very flexible, given the data generating software package utilized. Polynomial expressions up to the fourth power can be specified to create data resembling a wide variety of economic phenomena. Additionally, a stochastic error term can be specified to approximate empirical data. Finally, multiple copies of any data set using the stochastic error term will produce data that is unique yet which still conforms to the general parametric specification of the underlying polynomial. Table one indicates the procedure schematically.

TABLE 1

THE DATA GENERATION PROCESS

$$y = f(x_1^n, x_2^n, \ldots, x_m^n ; b_0, b_1, \ldots, b_m ; e)$$

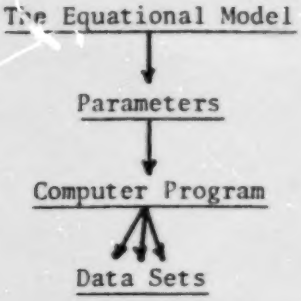
where:

$x_1, x_2, \ldots, x_m$ = independent variables

$b_0, b_1, \ldots, b_m$ = parameters

e = a stochastic error term

n = any real number



For best results the classroom pedagogy should use good examples, active student participation and real world allusions as well as guidance concerning the axiomatic nature of the economics discipline. The pre-designed data sets enter the process at the point of assigning homework. Each data set is self-contained, but may be closely linked to prior or subsequent sets, and has specific questions to be addressed. Through the process of answering the questions by analyzing the data, the student is actively engaging in the process of deductive reasoning. Coupling these student initiated insights with guided instruction and summaries by the instructor, is it argued that the student can become better equipped to transfer knowledge to other less familiar situations.

THEORETICAL ANALYSIS

Using a structured simulation approach as a technique requires a theoretical framework as a basis for posing relevant questions and situations. The theory underlying the formulated data units is standard microeconomic principles. The model used as a framework to exhibit the economic principles is the common cost-volume-profit (CVP) analysis.

CVP analysis has been used primarily as a short run optimization technique. Appropriately structured, the CVP model provides information relative to output volume, cost, product prices, and sales volume. The model, even in its simple form, is consistent with the axiom of profit maximization. While the actual use of the CVP approach in business decision making has not been rigorously established, the use of the model as an heuristic device for pedagogical purposes is quite appropriate.

The simple formulation of the model is deterministic i.e., the parameters are assumed to have known values. However, by assuming that certain variables are subject to defined distributions, the model becomes stochastic in nature. The use of stochastic variables allows the application of the CVP model under conditions of uncertainty. The model thus can be utilized to develop risk measures, to illustrate capital asset pricing, and to generally provide a basis for posing long run decision problems. The results of the stochastic model can readily be interpreted in terms of principles of economics.

The Deterministic Version

Elementary CVP analysis specifies the functional forms and assumes that management seeks to maximize short run profits under conditions of certainty. In conformity with much empirical research we specify a linear demand function and a quadratic cost function.

Let $P = a - bQ$

$TC = d + fQ + gQ^2$

$TR = p.Q = aQ - bQ^2$

$\pi = TR - TC = -d + (a-f)Q - (b+g)Q^2$

where P = Price
Q = Quantity
TC = Total Cost
TR = Total Revenue
π = Profit
a, b, d, f, g are parameters

The firm will maximize profits or minimize losses when the profit function is at its peak.
The necessary condition is:

$$\frac{d\pi}{dQ} = \frac{dTR}{dQ} - \frac{dTC}{dQ} = 0$$

specifically:

$$\frac{d\pi}{dQ} = (a-f) - 2(b+g)Q = 0$$

$$Q^* = (a-f)/2(b+g) \qquad (1)$$

Where Q^* is the profit maximizing level of output for the firm.
The sufficient condition is:

$$\frac{d^2\pi}{dQ^2} = \frac{d^2TR}{dQ^2} - \frac{d^2TC}{dQ^2} < 0$$

specifically:

$$\frac{d^2\pi}{dQ^2} = -2(b+g) < 0$$

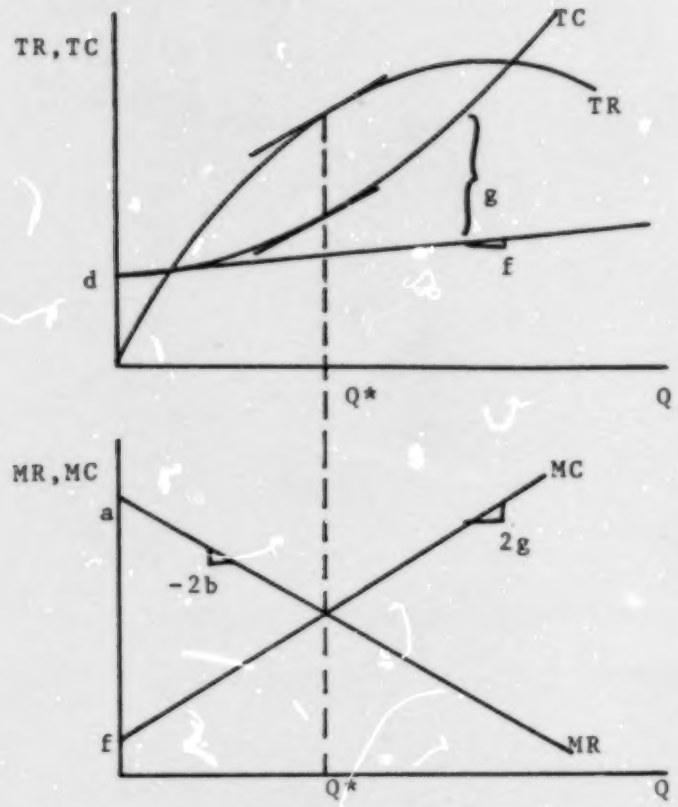
Alternatively, and in the common parlance of the economist, (1) can be expressed as:

$$(a - 2bQ) = (f + 2gQ) \qquad (2)$$

or

Marginal revenue = Marginal cost

It is instructive at this point to plot the functions.



The parameters have interpretive value. For the cost function, d is fixed costs, f is "variable" costs and g is "additional" costs or a sort of marginal cost. Nicely, and due to the quadratic specification of the total cost function, the rate of change of the slope of total cost is a constant 2g.

The economics of the CVP model implies that to maximize profits, management seeks the output which maximizes the difference between total revenue and total cost (TR > TC) or where marginal revenue equals marginal cost. The cost function exhibits diminishing returns throughout, which is not unexpected for firms operating within the normal ranges of short run capacity. The revenue function indicates, by its curvilinear nature, that the firm has some price setting power.

The Stochastic Version

Under conditions of uncertainty, even in the short run time period, different behavior is manifest for a risk averse management. The CVP framework can relatively easily accommodate stochastic disturbances in both the revenue and cost functions. For the sake of exposition our approach assumes a stochastic intercept for the demand and total cost function.

Let $\tilde{P} = \tilde{a} - bQ$

$\tilde{TC} = \tilde{d} + fQ + gQ^2$

$\tilde{TR} = \tilde{a}Q - bQ^2$

$\tilde{\pi} = -\tilde{d} + (\tilde{a} - f)Q - (b + g)Q^2$

where $\tilde{a} = a + \tilde{\varepsilon}$

$\tilde{d} = d + \tilde{\gamma}$

and all other variables are defined as before.

Assume that: $E(\varepsilon) = 0$; $E(\gamma) = 0$

$$\sigma^2_{\varepsilon} = \sigma^2_a \; ; \sigma^2_{\gamma} = \sigma^2_d$$

$$\sigma_{a,d} = \sigma_{\varepsilon\gamma} = 0$$

and the distributions of ε and γ are multivariate normal. Expected profit, $\bar{\pi}$, becomes

$$\bar{\pi} = -\bar{d} + (\bar{a} - f)Q - (b + g)Q^2 \qquad (3)$$

$$\bar{\pi} = -\bar{d} + \bar{m}Q - nQ^2 \qquad (3')$$

where $\bar{m} = (a - f)$

$n = (b + g)$

To maximize expected profit, the necessary condition is:

$$\frac{d\bar{\pi}}{dQ} = \bar{m} - 2nQ = 0$$

$$Q^* = \frac{\bar{m}}{2n} \qquad (4)$$

The sufficient condition is:

$$\frac{d^2\bar{\pi}}{dQ^2} = -2n < 0$$

Hence, optimal expected profit becomes:

$$\bar{\pi}^* = -\bar{d} + \frac{\bar{m}^2}{4n} \qquad (5)$$

after substituting (4) into (3').

Generally, the actual but uncertain profit is:

$$\tilde{\pi} = -\tilde{d} + (\tilde{a} - f)Q - (b + g)Q^2 \qquad (6)$$

$$\tilde{\pi} = -\tilde{d} + \tilde{m}Q - nQ^2 \qquad (6')$$

where $\tilde{m} = (\tilde{a} - f)$ and n is defined as before.

Therefore, actual profit, even when management produces Q*, is still stochastic.

$$\tilde{\pi}^* = -\tilde{d} + \tilde{m}Q - nQ^2 \qquad (7)$$

$$\tilde{\pi}^* = -\tilde{d} + \tilde{m}\left(\frac{\bar{m}}{2n}\right) - n\left(\frac{\bar{m}}{2n}\right)^2 \qquad (7')$$

It can be shown that the variance for profit, σ_π^2, is generally:

$$\sigma_\pi^2 = \sigma_\gamma^2 + \sigma_\varepsilon^2 Q^2 - 2\sigma_{\gamma\varepsilon} Q \qquad (8)$$

However, $\sigma_{\gamma\varepsilon}^2 = 0$ by assumption, which makes good economic sense in partial equilibrium micro analysis since price and cost are determined quite apart from one another. Therefore, the expression becomes:

$$\sigma_\pi^2 = \sigma_\gamma^2 + \sigma_\varepsilon^2 Q^2 \qquad (8')$$

Then, for the optimal output:

$$\sigma_\pi^2 = \sigma_\gamma^2 + \sigma_\varepsilon^2 \left(\frac{\bar{m}}{2n}\right)^2 \qquad (8'')$$

In words, the standard deviation of profit depends on the standard deviation of γ and ε as well as on output. As output increases so does the spread of the distribution around profit. However, since the distributions of γ and ε are assumed to be multivariate normal, the profit distribution, given output, is also normal.

THE SIMULATION PROCESS

Simulation for business decisions can take many forms from simple role playing to complex computer games. Within this milieu, data presentations for students in problem specific situations is an old technique. The data used may be actual empirical data or may be generated by the instructor for a given illustration. Both procedures involve problems of relevency, consistency, simplicity and production time. Such problems are generally known to persons engaged in the process of education. The simulation approach illustrated below is designed to overcome these problems and retain the theoretical integrity necessary in a simulation approach.

The crux of this approach is a computer program that generates data which may appear either deterministic or stochastic in form. The various levels of simulation can be used to illustrate a range of optimization problems. The functional form of the data, the range of the data, and, in cases involving uncertainty, the distribution of the data can be specified.

The data generating software package, as developed, provides the vehicle for the simulations with little loss of theoretical correctness. The package is designed to accept parametric specification inputs (all parameters lie in the realm of real numbers) for up to fourth power polynomials.

Randomness of the dependent variable can be simulated by specifying the desired correlation coefficient along with the mean and standard deviation of the error term. The resulting data are then plotted in normalized form and listed in an ordered array. By specifying a correlation coefficient between zero and one, the program approximates the desired fit through an iterative process. Hence, the distribution around the dependent variable is normal while the fit between the dependent and independent variables is specified by the user.
Symbolically: $y = f(x)$; a deterministic model

$$y^* = f(x,e); \text{ a stochastic model}$$

$$y' = y^* - y = e$$

where $e \sim N(0,1)$

Many options present themselves in this interactive program. The user may specify either a normal or rectangular distribution for the independent variable. He may choose the number of observations per each independent variable magnitude. The number of decimal places in the output, order of the data array and whether or not to have a standardized plot of the data are among the other options.

For the CVP framework, the data generating program serves well in deriving stochastic data for the cost and revenue functions. However, as shown in the prior section, the variance of the profit function is directly related to the output level as well as to the variances of the other two functions. The program is not designed to accommodate functional variance specifications for the error term and will tend to understate the variance for the profit function as output rises. We can only recognize this limitation and partially redress it by lowering the correlation coefficient for the profit function data generation below that of the cost and revenue functions. We argue that the loss of theoretical accuracy is minimal in relevant ranges of output and is acceptable for pedagogical modeling.

The computer simulation program was used as the tool to design four data analysis sets. Each of the sets focused on a particular economic area and one or more concepts. These data sets were instituted as required exercises in an MBA Managerial Economics course at UH-CL in the spring semester of 1983. The data analysis sets appear in Appendix A and the computer program along with an example appears in Appendix B.

The four data analysis sets were assigned and graded with the sum of the four scores weighted equal to an examination score. The students knew that the data sets were new and they were invited to look for errors and or improvements in them. There was no attempt to perform an experimental versus control group test of differences in performance. At this stage, the authors were more interested in the accuracy, relevance and acceptability of the data sets.

Student response to the data sets was generally very favorable. Students in the Managerial Economics courses had requested more application oriented

material for several semesters. Table One below capsulizes the student performance on the data sets and examinations. It is interesting to note that the scores on the data sets trend upward as do the examination scores.

TABLE ONE

DATA SET	AVERAGE	EXAMINATION	AVERAGE
1	20,70	1	76,58
2	21,16	2	81,42
3	22,45	3	82,64
4	21,18	--	-----

The students were also asked to complete a survey at the end of the course concerning their experience with the data sets. Five statements were evaluated on a five point Likert scale from strongly agree (1) to strongly disagree (5). A sixth question asked for ways in which they thought the data sets might be improved. Table Two summarizes the results of the five Likert scaled questions.

TABLE TWO

STATEMENT	SCALE RATING (% RESPONDING) 1	2	3	4	5
1. The data set problems were helpful in understanding the course material.	42	50	8	0	0
2. The data set problems were challenging.	67	33	0	0	0
3. The data set problems required some integration of the concepts presented in the course.	50	50	0	0	0
4. The data set problems should be utilitized as a regular feature in the course.	58	33	9	0	0
5. The data set problems, in some way, enhanced my performance on course examinations.	25	58	8	9	0

Student comments concerning ways in which the data sets might be improved included:

a. Making the questions clearer
b. Tightening up the data distributions
c. Timing of the data sets

In all, the authors are pleased with the first round of results for the simulation procedures as explained above and introduced in the Managerial Economics classroom.

SUMMARY AND CONCLUSIONS

This paper presented the elementary mathematics behind the traditional cost-volume-profit model of the business firm in both deterministic and stochastic forms. It was shown that the structure could be modeled by a simulation process to derive a wide variety of data analysis sets for pedagogical use in the classroom. The data sets can be used to aid students in applying concepts learned in the classroom with real world overtones.

The results of four such data sets completed by students in a Managerial Economics course were summarized. Initial feedback indicates that the data sets have positive value to the students. The examples provided were basic, but the procedures are adaptable to complex problems. By assuming multivariate normal distributions, risk considerations and probability measures relating to different levels of profit can be incorporated into the analysis. The student can be progressively introduced to more difficult decision problems within a consistent framework. The authors feel that work on this approach should continue and be expanded into simulations of actual firm data as well as into other theoretical areas.

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APPENDIX

The Data Analysis Sets

ECONOMICS 5136
Problem I
Demand

Assume that the data below have been collected properly in an attempt to estimate the demand for a company's product. Although collection of the data was carefully completed, other aspects of the study may or may not be in conformity with good economic or statistical theory. You are to address the questions below on the basis of your own knowledge (including references) but using only the information provided here. The measure for output is whole units and for price, the measure is dollars.

1. If the demand function is properly specified with a bivariate statistical form, then what are the approximate slope and intercept parameters? Provide a plot of the data and a sketch of the line of "best fit".

2. Determine the price elasticity of demand between the output levels of 4 and 5. Use the line of best fit sketched in 1 to determine the prices and quantities to be used.

3. What is the algebraic specification for the marginal revenue function associated with you demand function?

4. Verify that MR = P(1 - 1/e) for the results found in 2.

5. If the firm is a revenue maximizer, at what approximate level of output will it produce?

6. What is the price elasticity of demand at the output level indicated in 5? Demonstrate that you are correct by solving the equation in 4.

7. If product Z is a competing brand and its price rises, then what would you expect to happen to the demand function in this problem?

8. Since the original statistical specification for the demand function omitted a variable for the price of substitutes, what can be said about your demand function estimate? (Be specific).

9. If the statistical version of the demand function is estimated to be:

$$P = 5.87 - .54\,Q \qquad R^2 = .63$$
$$(.18)$$

Where P = Price
Q = Quantity
(The value in parentheses is the standard error of the coefficient.)

Then what interpretations can be provided for the equation?

10. If the error term (not shown here) were seriously heteroscedastic, what would you deduce concerning predictions made with this equation?

X	Y
12	.00
12	.11
11	.50
11	.21
10	1.20
10	1.10
9	2.03
9	1.84
8	1.61
8	1.29
7	2.19
7	1.91
6	2.74
6	2.38
5	3.72
5	3.61
4	4.19
4	3.91
3	4.74
3	4.19
2	5.08
2	4.91
1	6.49
1	5.67
0	5.97
0	5.68

X = Quantity

Y = Price

ECONOMICS 5136

Problem II

Cost

Assume that the data on the next page have been collected by the cost accounting department of a manufacturing concern. The division manager has requested that you address the questions below from an economist's viewpoint. You are about to come up for your annual performance review and want to make a favorable showing.

1. Determine total costs, total variable costs and marginal costs. Accounting has determined that fixed costs = $1.

2. What is the economic shutdown level of output for this plant?

3. If the product of the plant is sold in a competitive market, can you determine the firm's supply schedule? If so, do it.

4. If the firm's labor costs are $5/hour, determine the marginal product of labor. This is a short run model.

5. Is diminishing returns to the variable factor occurring? How do you know.

6. Given only this data, is it possible to tell if the firm is making a profit? Why?

7. Given only this data is it possible to determine the opportunity cost for any given level of output? How or why?

8. If the financial debt service expense of the firm rose, how would the output for this plant be affected? Why?

9. If labor costs rose to $6/hour due to a union wage negotiation agreement, how would the output for this plant be affected? Why? Would the capital/labor ratio be affected? Why or why not?

10. If this data had been collected empirically by an economist, would cross-section or time series procedures have been more appropriate? Why?

N	X	Y
1	9.0	74.80
2	.5	1.61
3	4.5	13.59
4	6.0	33.83
5	5.0	24.95
6	10.0	101.32
7	8.5	67.63
8	1.5	3.57
9	4.0	11.31
10	2.5	10.19
11	6.5	40.07
12	9.5	84.28
13	3.5	5.29
14	1.0	6.17
15	3.0	9.38
16	5.5	20.14
17	7.5	55.10
18	2.0	5.43
19	8.0	59.95
20	7.0	45.29

X = Output in units per time

Y = AVC in dollars